CHAPTER 1

INTRODUCTION

Metals define the technological and economic character of the urban era as stone defines the character of the millennia during which Stone Age people first tried to shape tools by hammering or cutting rocks. Ancient metal technology stands as one of the greatest achievements of mankind. The study of metal artefacts to infer the metallurgical techniques used in ancient times forms an important part of the archaeologist's quest for knowledge about age-old technological practices.

Thousands of bits of evidence collected thus far suggests that man first viewed metals as individual and puzzling representative of a new form of matter. He began by hammering native gold and copper or meteoric iron. But he did not appreciate their character until he had learnt to reduce them from their ores and melt and cast a variety of metals. Smelting was the main invention through which he first gained an understanding of metals as the derivative of varicoloured, many faceted mineral stones by a strange process of fire, and that they are lustrous, ductile and malleable. (Wertime 1964: 1257-67)

Whatever be the place of metals in history, their various debuts as useful materials are not clearly defined. With the emergence of knowledge of metals and metallurgy, hunting, pastoralism and primitive agriculture got evolved into a durable economy contributing to the all round development of human life. The discovery and gradual acquisition of mastery over Iron
was an important step in this direction. It gave man a very useful metal that could, at once, achieve adequate hardness and sharpness to meet nearly all his requirements in peace and war, thus heralding the onset of what has been called the 'Iron Age'.

Iron is symbolically designated as "Fe" (derived from the Latin word *Ferrum*). Being one of the widely used metals in the world, it is best known for its physical and chemical properties, use as a high-strength structural material and for steel manufacturing. The discovery and use of iron by man come last in the inventory of the basic metals, as it does after copper, tin, lead and many of their alloys and it marked one of the greatest milestones in his progress (Chakrabarti 1976: 114-124). The juxtaposition of a common commodity whose production and processing often incorporates great technical sophistication to bring out properties far in advance of any other material, makes its history, perhaps, most interesting of all metals and is very true in the case of iron (Craddock 1995: 234).

Iron is known to have made humble beginnings in one or more centres and played a minor/subordinate role alongside copper or bronze. Even though they could attain temperatures to smelt copper, achieving temperature required to smelt iron was out of their reach for a long time due to the fundamental difference in metallurgy. The earliest known use of iron comes from West Asian sites namely, Tel Asmar, Chagar Bazar and Mari in Mesopotamia, Alaca Huyuk in Anatolia and Egypt (Allchin & Allchin 1968: 207). These are dated to first half of the third millennium BC. Iron objects belonging to second millennium BC were discovered from Yorgan Tepe and Tel Halaf in Mesopotamia, Transcaucasia, Syria, Palestine and Persia. Although the beginning of deliberate iron smelting is obscure, the earliest
evidence of smelting of iron ore to produce a spongy bloom to make wrought iron tools has been assigned to the third millennium BC. The special process required to convert iron into steel seems to have been known in Western Asia from the end of the second millennium BC. (Allchin and Allchin 1968). It is possible that the early rare iron objects were produced from accidental extraction of the ore. Some of them may have been produced from naturally occurring meteoric iron. (Tylecote 1976: 40-51).

In the Indian sub-continent, the tradition of using iron has been indicated by the large number of metal objects unearthed from different settlements. Archaeological investigations have amply shown that the metal, in its technological and economic aspects, had come into use sometime at the end of second millennium BC. Excavations at Atranjikhera (Gaur 1983) and Hallur (Rao 1971) have brought to light the earliest iron objects in India dated by radiocarbon to 1100 BC and 900 BC respectively. A plethora of iron objects have been unearthed from several other sites in India reflecting its widespread use from Early Historic period onwards.

In northern India, the earliest iron is reported from Ahicchatra, Atranjikhera (Gaur 1983), Hastinapur (Lal 1955) and Kausambi (Sharma 1960) in association with Painted Grey Ware Culture (PGW), dated between c.1100-700 BC. Chirand, Mahisdal and Pandu Rajar Dhibi (Tripathi 1990) in eastern India have yielded iron in pre- Northern Black Polished Ware (NBPW) context, in association with Black- and-Red Ware dated to c.700 BC.(Agarwal 1984). A remarkable continuity from Chalcolithic stage to Iron producing stage is observed at Nagda, Eran, Prakash, Bahal and Ujjain
in Central India and the Deccan, where iron is found in pre-NBPW layers suggesting its beginning by around 1100 BC.

In western India, the iron working has been traced to the Chalcolithic context. The scene here is confusing, in the sense, that iron appears in quite an early Chalcolithic context at Ahar but its ramifications are not yet archaeologically understood. Jodhpura and Noh in Rajasthan yielded iron in the PGW and Black-and-Red Ware level respectively (Agrawala and Kumar 1976). Early iron has been reported from pre-NBPW phase along with Black-and-Red Ware of Somnath-III, Nagara-I and Timbarva-I in Gujarat. NBPW levels of these areas generally belong to a late phase (450-300 BC). Roy (1986) has placed the iron bearing pre-NBPW levels of these sites between c.700-600 BC. The aforesaid discoveries indicate that at various localities in India occurrence of iron in association with different cultural phases had become fairly common.

The large-scale production of weapons during 7th century BC indicates that the contemporary iron industry was geared to meet the military requirements of the ambitious Chiefs of the Mahajanapadas. Thus, iron began to assert itself as a metal of great utility in domestic, agricultural and defence activities. By the 4th century BC, the knowledge of iron technology achieved a mature stage by spreading all over the country (Hegde 1991). This is very well reflected in the occurrence of a wide range of weapons and implements recovered from archaeological levels dated to the 6th and 5th centuries BC at Taxila (Marshall 1951), Rupar (Sharma 1956), Hastinapura (Lal 1955), Sonkh (IAR 1966-67), Kausambi (Sharma 1960), Rajghat (Narain and Roy 1977) and Ujjain (Banerjee 1965). The main types from these collections were arrowheads, spearheads, daggers, knives, parallel-
sided swords and leaf shaped spearheads. The most common types were chisels (with rectangular and square sections), straight-sided knives, ploughshare, sickles, nails and socketed axes. Monuments like Asokan pillars and cave temples belonging to the last quarter of the 1st millennium BC are testimony to the excellent quality of ancient Indian chisels.

There are divergent views regarding the late development of iron smelting in India. Until late 60s, many archaeologists believed that Indian iron technology was borrowed from Iran. Gordon (1950) approached the problem of beginning of iron in India and its history from a diffusionist standpoint. He could find no evidence for the use of iron in India before 250 BC. Wheeler (1959) held that India received the necessary knowledge after the incursions of Achaemenids by c.500 BC. Lallanji Gopal (1960) states that it was the Aryans who brought iron technology into India. The Allchins (1968) expressed the view that the smelting of iron was first developed in Asia Minor, and between 1800 and 1200 BC it remained a monopoly of the Hittites. The breakdown of the Hittite Empire in 1200 BC provided the necessary stimulus for the diffusion of iron technology towards the east as well as the west. Pleiner (1971) made a detailed analysis of literary data and concluded that iron penetrated the Indian subcontinent after the arrival of Aryans with its the sporadic occurrence around 1000 BC.

Scholars have variously ascribed authors of iron in India to Aryans (Lallanji Gopal 1960), PGW Culture (Banerjee 1965) and Black-and-Red Ware Culture (Subrahmanyam 1966). Banerjee (1965) discussed in detail all the early Indian archaeological contexts in which the iron objects were found. He opines that the Painted Grey Ware culture of the Gangetic Doab dated to
1000 BC as early iron users of India and he further identifies them with the Aryans. On the basis of archaeological data, Subrahmanyam (1966) concluded that the earliest evidence of iron came from the Gangetic Doab dated to 10th-11th centuries BC. Around 2nd century BC, diffusion took place from the Doab to other parts of the country. He identified three chronological and geographical phases in the early use of iron. During the first phase (between 10th-11th and 7th centuries BC.), iron was limited to the Doab with minimum practical usage. In the second phase (from 7th to 4th centuries BC.), use of iron spread to eastern UP, Bihar, Central India and Gujarat with an increase in quantity and functional types of iron objects. In the third and last phase (4th century BC onwards) it had moved towards Orissa and South India.

Tripathi (1973) and Chakrabarti (1973) independently surveyed the available data along with radiocarbon dates. While Tripathi supported a diffusionist theory, Chakrabarti disagreed with it. There is not sufficient archaeological evidence to support the view that Indian iron technology was developed indigenously. Chakrabarti (1974) argued that the early occurrence of iron in the post-Chalcolithic iron bearing levels at sites like Nagda indicates its indigenous development. He discarded the diffusionist theory saying that available data did not support any "a priori" diffusionist hypothesis. Later on Chakrabarti (1976) and Sahi (1980) argued for an independent origin of iron in the Indian sub-continent. Further, Chakrabarti argued that there were a number of early iron using foci in India during the close of the second millennium BC. and there was no reason to link the beginning of iron in India to any influence or movement of people from West Asia (Chakrabarti 1985:75). Iron metallurgy in India could have begun as an offshoot of copper metallurgy. Sahi and Hegde emphasised this
in the Indian context (Sahi 1980; Hegde 1981). Prakash and Tripathi (1986) also tried to identify six iron using foci in Indian sub-continent and argued for indigenous development of iron technology in India.

Research based on the literary evidences is emphasised by Neogi (1914); Schoff (1912); Banerjee (1927); Kosambi (1963); Pleiner (1971) and Agrawal (1971, 1982). The historical importance of iron was first brought to light by Neogi (1914) in his work which synthesised a wide range of data by systematising geological, ethnological, archaeological, metallographic and literary aspects. Schoff (1912: 230) refers to the import of fine grade steel into the Roman world from some eastern source. Banerjee (1927: 128) discussed definite mention of iron in the Rigveda, with the help of supportive statements from post-Vedic literature and comparative statements on the subject regarding various authors. From Rigvedic references, he infers ayas as a “very hard metal, tough, tenacious, malleable and ductile, one that could be sharpened, at the same time, into murderous weapons, easily forged or worked into tools and beaten into desired shapes and sizes” (Banerjee 1929: 440). He further opines that the use of iron and steel in the Rigvedic Age is further substantiated by the Rigvedic hymns referring directly or indirectly to swords and razors of iron. Kosambi (1963) pointed out clear evidences of iron ploughshare in the Buddhist canon “Suttanipata” indicating the wide use of iron for agricultural purposes. Pleinier (1971:5-36) gives particular attention to the terminology of iron in Sanskrit and Pali literature till the period of Arthasastra with a brief discussion on metallography. He suggests 800-500 BC as the period of penetration of iron into the material culture of India. He further opines that the developed and prospering Iron Age flourished only since 300 BC.
Thus, as can be seen, iron has been a topic of archaeological research and academic interest for a long time. From the above survey however, it is clear that most of the earlier studies were mainly concerned with the antiquity of the metal based on the narrow perspective of its archaeological occurrences, conventional categorisation, classification and literary information. Eventually from cultural-historical approaches, emphasis shifted to technological analyses based on metallographic studies of ancient iron objects from different areas and different periods. Researchers started taking an interest in the composition of early iron objects. Data regarding Iron Age from different regions and periods were subjected to compositional and technological analyses. A great deal of research works in the field of metal technology and metallurgy has been published in the last four decades. Many excavation reports also throw light on various facets of iron technology in ancient India (Lal 1955; Sharma 1960; Banerjee 1965; Mehta et al. 1975; Deo 1981-83; Gaur 1983).

Hadfield (1912) made a significant attempt to analyse a few dated objects from Ceylon. Metallographic study of iron objects from Prakash (Athvale 1967), Alamgirpur (Tandon 1967-68), Kausambi (Prakash & Singh 1968), Takalghat and Khapa (Munshi and Sarin 1970), Mahurjhari and Naikund (Gogte 1982, 1983), Rajghat (Bharadwaj 1973), Dhatva (Hegde 1973 a&b); Pandurajar Dhibi (Chattopadhyaya and De 1989); Bharudih (Chattopadyaya and Ghosh 1982); Tadakanahalli (Agrawal et al. 1980-81), Ataranjikhara (Gaur 1983), Hulaskhara (Agrawal et al. 1986), Khairadih (Agrawal et al 1990), have been carried out. Athavale (1967) noticed black slag inclusions and equiaxed ferrite grains with small amount of pearlite grain boundaries in the iron objects from Prakash. Bharadwaj (1979) commented on some aspects of early iron technology on the basis of
chemical and metallographic study of a few iron objects and slag from Early Historic level of Rajghat and determined the nature of iron objects, ancient metallurgical operations and the nature of the ores used. Hegde (1973a) carried out analysis of iron objects from the Early Historical iron-smelting site at Dhatva in Gujarat, aimed at solving technological questions. Ghosh (1964) discussed the primitive iron making in contemporary India. Rahman and Subbarayappa (1966) wrote about native method of bar iron production in south India. Prakash and Igaki (1984) give details regarding ancient iron making at Bastar District of Uttar Pradesh.

The problem of Indian iron did not attract socio-economic historians much. Bose (1945) has discussed socio-economic aspects of the Early Historic period making brief references to the mention of iron in Buddhist literature (the Jatakas). Kosambi suggested that large-scale settlement in the Doab was not possible without effective use of iron (Kosambi 1963). He further suggests that the growth of the Magadhan empire depended largely on its control over the mineral resources of east India particularly on iron ores (Kosambi 1965:84). According to Sharma, the spurt in agrarian activities could not have been possible without the clearance of jungles in the middle Gangetic alluvial zone which has heavy rainfall (Sharma 1983 :120). Further, plentiful supply of iron ores and improvement in the technology of their manufacture played a significant role in agriculture and handicrafts production. Sharma also suggested that at any rate, despite unimpressive material remains, it was fair to infer that the use of iron in pre-Mauryan times made an important contribution to the overall development of economy (Sharma 1983:123). On the basis of Megalithic data from Vidarbha region, Deo (1985: 90-94) tried to draw inferences regarding ecology, economy, social structure, technology and the possible status of
persons in Megalithic social organization. He concluded that due to the negligible number of agricultural tools and the absence of ploughshare in the entire repertoire of iron artefacts at practically all the sites in Vidarbha and the large percentage of cattle bones indicated that these people were essentially mobile pastorals. Further he drew attention to the problem of contacts between the Megalithic culture and contemporary non-Megalithic cultures. Chakrabarti (1985: 77) asserted that archaeologists should try to understand the Iron Age phenomenon in its economic and cultural aspects in different regions. According to Ahmed (1991:222), with the development of iron technology, new settlements were established. This was done by exploiting the till then unexplored resources of iron to cope with the growing demands.

THE PROBLEM

The two prevalent trends are thus, to study iron from: 1. Scientific and 2. Socio-cultural viewpoints. Through scientific analysis, scholars have tried to solve problems pertaining to technology, such as, determining the nature of iron ore used, location of the ore, preparation of the ore, its composition, nature of the iron objects, ancient metallurgical operations, heat treatments, composition of the metal, evolution of techniques etc. At the same time, socio-cultural themes concentrated on understanding early society and economy, such as, the stages in economic history of the material, social and economic institutions in ancient India, economic organisation and relevance of communication, social control etc. All the aforesaid works usually emphasise any single aspect and lack a holistic approach.
Mention must be made here of works which try to understand the cultural configurations in India from a regional and ecological viewpoint. Distinct from generalisations for India as a whole, the need for regional studies has been emphasised by Ghosh (1953). Amongst these, Subbarao’s (1958) efforts to classify the regions ecologically (Subbarao 1958) and Malik’s (1968) correlation of natural regions with present day linguistic zones is noteworthy. Subbarao divided the geographical landscape of India into 1) areas of attraction 2) areas of relative isolation and 3) areas of isolation (Subbarao 1958:12). As per Subbarao’s division, Gujarat forms the area of relative isolation. Although several Early Historic settlements have been excavated in Gujarat, these excavations were conducted more than two decades ago. Hence, in terms of methods of excavation, the questions they sought to answer, the manner of reporting and the recording and analysis of the artefacts presents several limitations. A large number of iron objects have been recovered from these excavations, but a systematic account of the material evidence is yet to be attempted. Thus, although a lot of material of the Early Historic period of Gujarat is available, the information obtained from them in actual terms of an understanding of the Early Historic society, economy, technology and their interplay is comparatively very little. Material science methods and their applications in analysing and interpreting artefacts from various aspects have come a long way. New archaeological concerns have also led to new questions being asked and more exact methods are being adopted for the recovery, recording and analysis of data. Thus, in view of the inadequacy of the earlier studies, there is an urgent need for a comprehensive re-look at the early historic material with a new and wider perspective.
The present work is an attempt at an indepth technological analysis of iron objects recovered from some early historic sites in Gujarat. Available literary references to ancient metal workers do not contain any account of their working activities. Therefore, it is not easy to reconstruct the progress of their technical skills in a sequential order. All that we have are the metal objects recovered from stratified contexts of excavated sites and slags. Metallurgy is one of the scientific methods that can be used to understand and assess the level of iron technology achieved by the iron using communities. Detailed metallurgical studies of a number of stratified metal objects of different periods can throw some light on this.

A beginning was made by Hegde (1973a and 1973b) who carried out analysis of iron objects from the Early Historical iron-smelting site of Dhatva in Gujarat with an aim to solve certain technological problems. The problems he tried to solve are: location of the ore, composition of the ore, evidence of ore preparation, types of fuel used for smelting, composition of the extracted metal and methods used in the fabrication of metallurgical techniques. He has pointed out similarity in technological practices between the Early Historic iron smelters and the modern Ghadi Loharias of Gujarat. He tried to generalise the technology of Early Historic iron in the region of Gujarat based on the evidence from a single site. However, his work did not deal with the regional characteristics of iron implements in their technological and socio-economic aspects.

The understanding of the nature and character of metallurgy of Early Historic period of Gujarat still remains in its embryonic stage due to the lack of a holistic approach, that is, an integration of metallographic and socio-economic approaches.
This thesis is an attempt to overcome the aforesaid discrepancies to some extent by adopting a scientific approach towards a thorough understanding of metallurgical processes and then trying to relate the findings to the socio-economic aspect in the limited context of Early Historic period of Gujarat. A complete study of unearthed stratified iron objects from archaeological excavations and explorations has been done. The analytical and metallographic aspects of iron objects recovered so far from excavated sites are dealt with by emphasising on technology and socio-economic significance of the metal. The present study incorporates analysis of iron objects recovered from excavations of the Early Historic sites of Nagara, Shamalaji, Devnimori, and Timbarva in Gujarat. Along with excavated archaeological specimens, contemporary recycled scrap material is also analysed.

The objectives of the present work are:

1. To assess the geological setting, chronology and material testimony of the Early Historic sites yielding iron in Gujarat.

2. To classify iron objects from these sites on the basis of their morphology and probable function.

3. To analyse the typology of the iron objects to know the major types and their distribution in different sites.

4. To undertake chemical and metallographic analyses of iron implements with a view
a. To know chemical composition of the object to understand the nature of the iron in terms of its purity and percentage of alloying element.

b. To understand the microstructure of the objects to know technology that is, methods of production, heat treatment etc.

c. To infer the changes in production technology with regard to its typology.

5. To assess how reliable these metal types are for establishing cultural and economic aspects of this region.

6. To study the traditional iron working practices and observe the resultant microstructure.

7. Finally, to appreciate the role-played by iron technology in the development of Early Historic communities in Gujarat.

With the help of archaeological data, the investigator has been trying to find the cultural traits connected with technological developments in the specified period. With typological, metallurgical, chemical, and ethnographical inferences, an attempt is made to evaluate the technological developments.

The scope of the study lies in extending such an approach to other regions and periods, which would allow inter-regional and inter-period correlations to provide answers regarding the antiquity and evolution of iron technology in India. To make the study of iron production in antiquity easier, the methods employed in modern as well as pre-industrial iron production are explained in the next chapter.